Overcoming The Technical Challenges of Hybrid Systems

- Commercial Examples




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NORTHERN POWER SYSTEMS
power without limits

About Northern Power Systems

- 25+ years of experience, 800+ projects on seven continents
- Specialist in on-site power generation systems
  - Renewable and co-generation
  - Hybrid and remote systems
- Turnkey systems integrator -- design & build
- Technology neutral approach

The Northern Approach

Northern works collaboratively with customers from thought to finish, providing:

- Site analysis
- Project and financial assessment
- Engineering study
- Metering and data collection
- System engineering and design
- Equipment and procurement
- System construction and site prep
- Installation, commissioning, staff training
- Monitoring and control
- Maintenance

Why hybrids with renewables?

- Lower energy costs
  - Free fuel from biogas, wind and sun
  - Economic uses of recovered heat through Combined Heat and Power (CHP)
  - Buy-downs, tax credits, other incentives reduce installation cost and shorten payback period
  - Paybacks as low as 2 years in some states
- Dramatically reduced emissions
- Increased power reliability
- “Diversified energy portfolio”
- Engineered for low maintenance

Agenda

- The challenge of hybrid integration
- Solutions illustrated by case studies
  - Grid interconnection
  - Electricity storage
  - Load manipulation
  - Thermal storage
- Winning designs
  - Co-generation & photovoltaics
  - Wind-diesel
- Hybrid systems of the future
  - Hydrogen

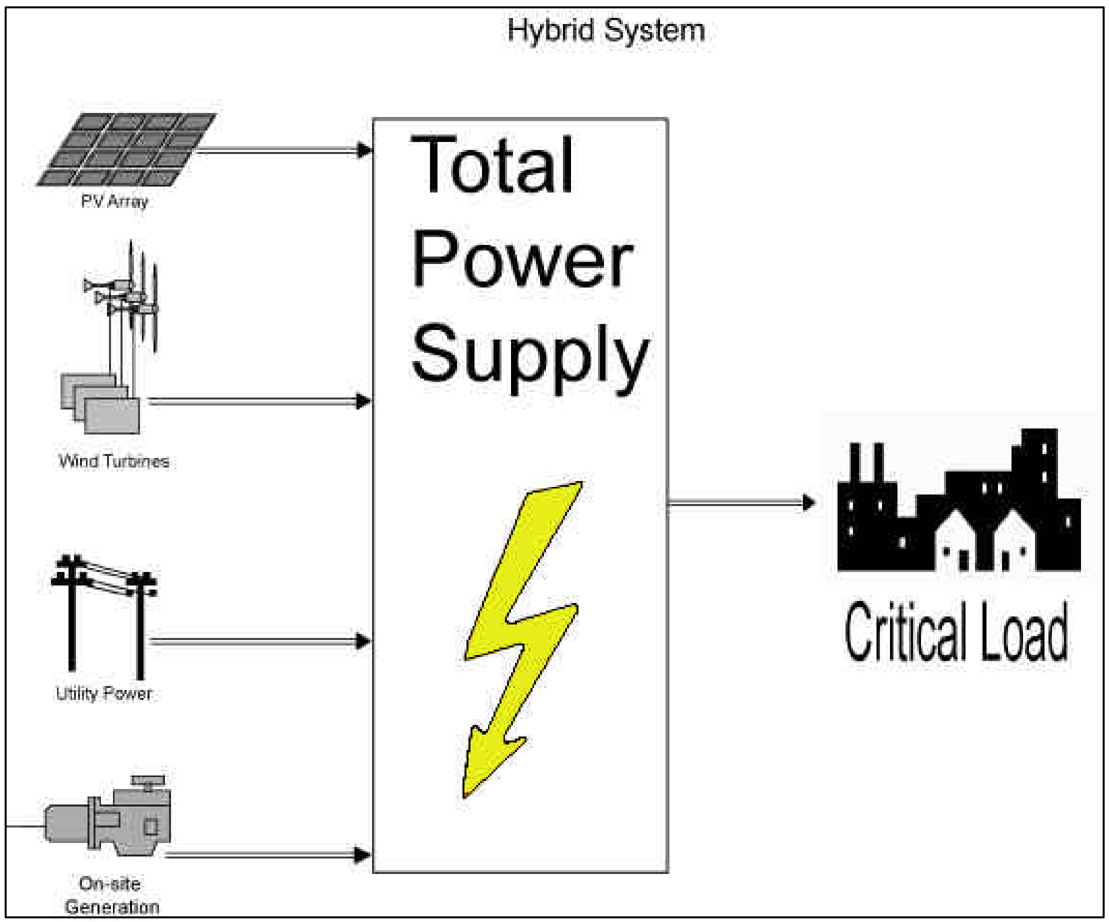
Why is it hard?

1. All generating assets have unique operating constraints and benefits
   – Renewable resources are intermittent
   – Fossil fuels expensive & dirty
   – Optimal generation may only be in narrow operating ranges
   – Each asset typically has different power characteristics

2. Load is inherently variable – it's a moving target

It all has to add up!

GENERATION must equal LOAD



The Challenges of Dispatching

- Individual integration of each asset type is generally well understood by the technical community
- Power quality challenge: frequency & voltage control, VAR control, grid stability, “flicker”, harmonics …
- Challenges increase disproportionately when multiple assets are combined
- How will you implement your dispatch strategy?
  - Who turns the engine on and off?
  - How is the engine optimally throttled to follow wind generation?
  - How do you keep engine at optimal RPM level while load varies?
  - What do you do if load suddenly drops sharply?
  - What do you do when you have excess power in the system?
  - How do you control peak shaving?

It's More Than Technology

- At the end of the day, it's all about <u>economic performance</u>
- What is the optimal dispatch strategy?
  - Minimize fuel use or emissions?
  - Maximize efficiency or flexibility?
  - Figuring in operations consequences for maintenance
  - Variable fuel prices, load, availability of renewable resources
  - Constraints imposed by permits, incentives, subsidies
- How do you predict <u>system behavior</u> and thus <u>economic performance</u>?

Advanced economic modeling capability is key

How it can be done

- Add more brains, Programmable Logic Controllers (PLCs)
  - The missing link! – the most under-estimated component of hybrid systems
  - Design and programming is absolutely critical
  - Optimal performance through ongoing tuning
- Create some flexibility in the system
  A. Make it somebody else's problem e.g. a utility
  B. Electrical storage
  C. Load manipulation
  D. Thermal storage

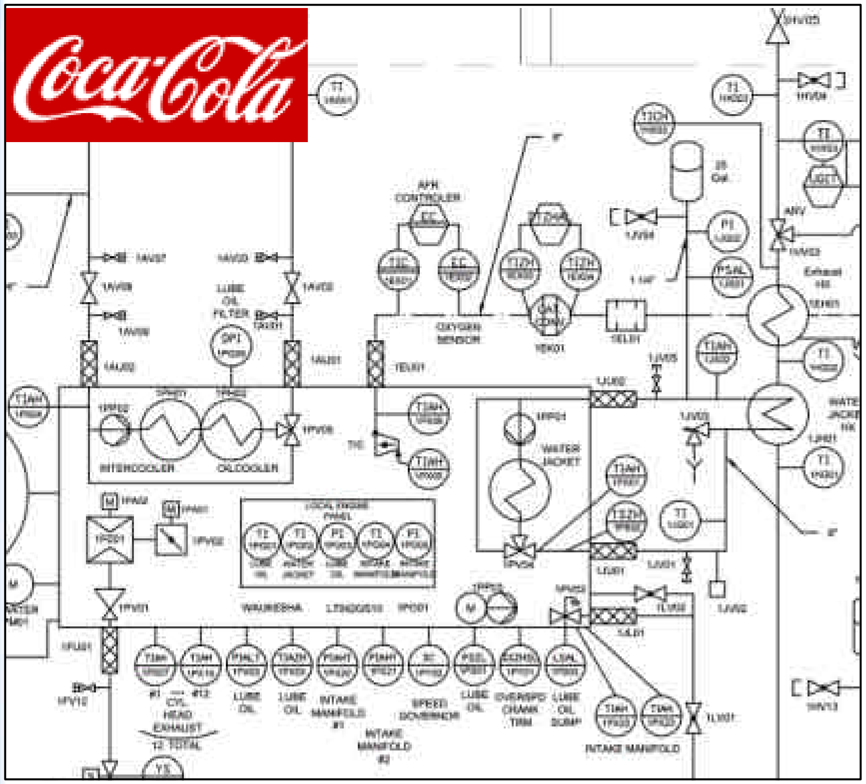
+ renewable hydrogen generation

(+ water pumping)

A. Making it somebody else's problem

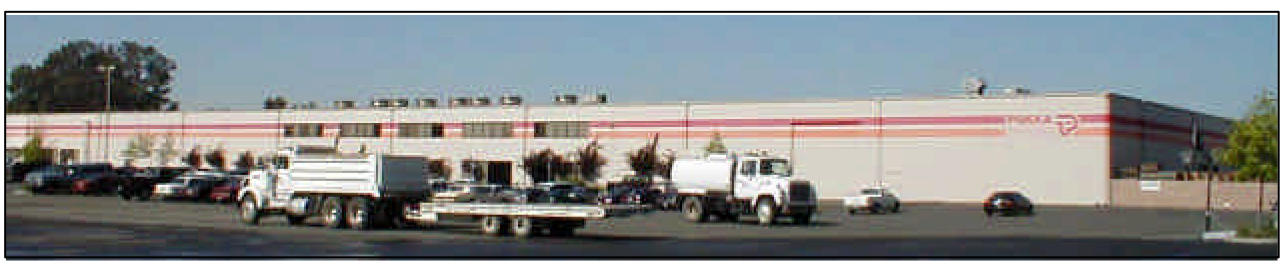
- Grid-parallel operation
  – Site is supported by utility and on-site system at the same time
  – Dump (sell) excess power, fill gaps with utility power
- The best of all worlds – critical load support architecture
  – Grid supports site if on-site system is down
  – On-site system carries critical loads if grid is down
- Complex interconnection requirements
- The reason for stand-by charges

Project example: Pokka Beverage



- 1 MW gas-fired CHP system
- 70% electricity and 30% hot water needs
- Cost of electricity produced = 6c
- 40% reduction in emissions
- Selfgen incentive
- 2.5 year payback

- Critical load support
- Unique architecture
  - Very involved project working with utility



B. Electrical storage

- Batteries
  - Temperature sensitive
  - High maintenance
  - Expensive
- Ultra capacitors
  - Short duration
- Fly wheels
  - Promising, but not quite there yet

Zzyzx , California

- Hybrid system with battery storage

- Remote UC research campus
  - Photovoltaics
  - Propane generator
  - Lead acid batteries
- Sophisticated controls
- Remote monitoring & control

C. Load manipulation

- Manipulate the “load” side of the equation
- Reduction in generation
  - Start shedding non-critical loads
  - Can be multiple levels

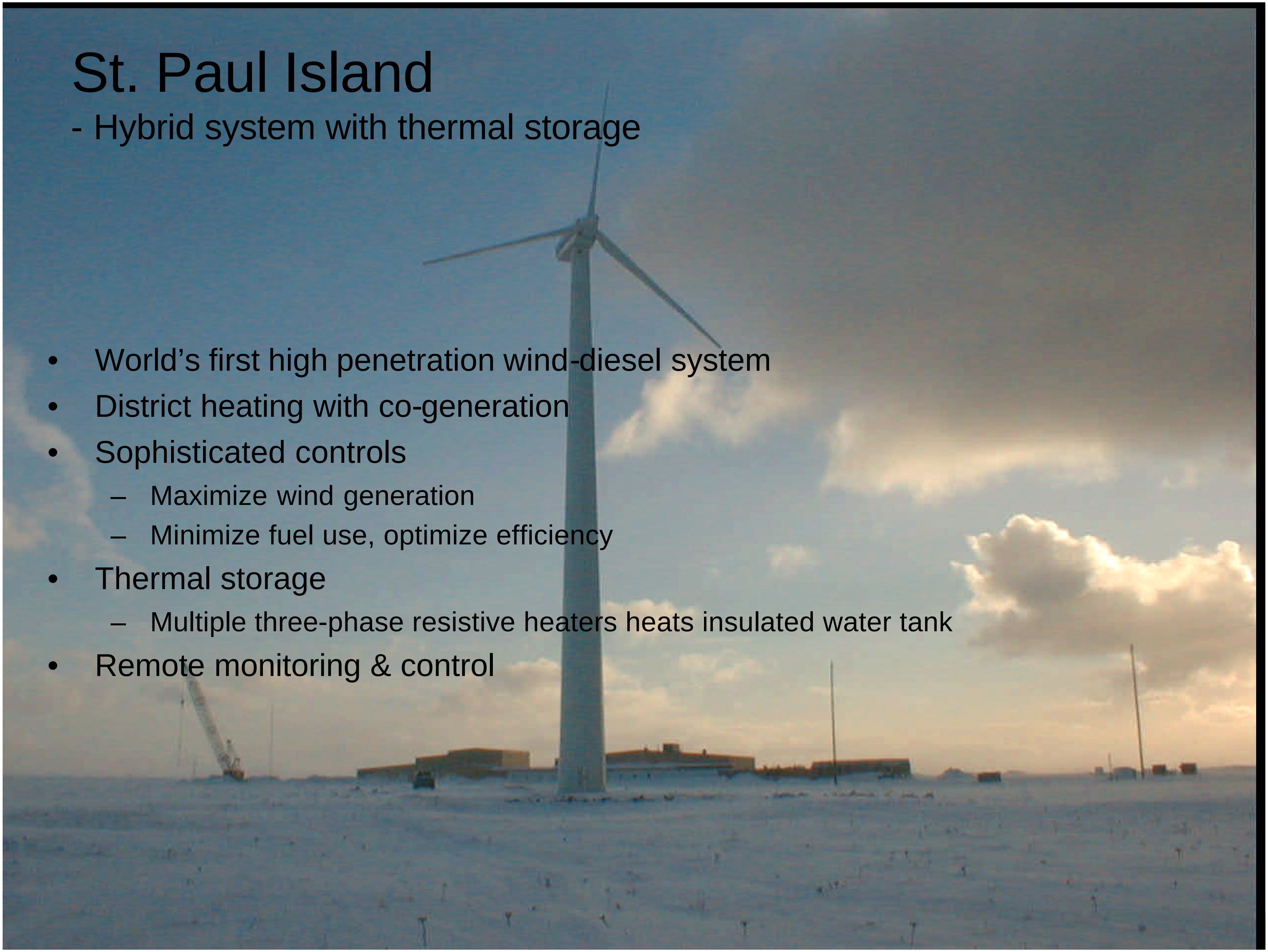
Black Island

- Hybrid system with load manipulation

- McMurdo communications link
  - Four wind turbines
  - Photovoltaics
  - Three diesel engines
- Sophisticated controls
  - Four levels of load shedding
- Remote monitoring & control
- 99.99% reliability
  - 197 MPH winds
  - -70 degrees F

D. Thermal storage

- Excess generation
  - Turn on thermal generation and store
- Electrical boiler
  - Store heated water and apply to domestic hot water
- Chiller
  - Store ice or cold water and apply to cooling/AC

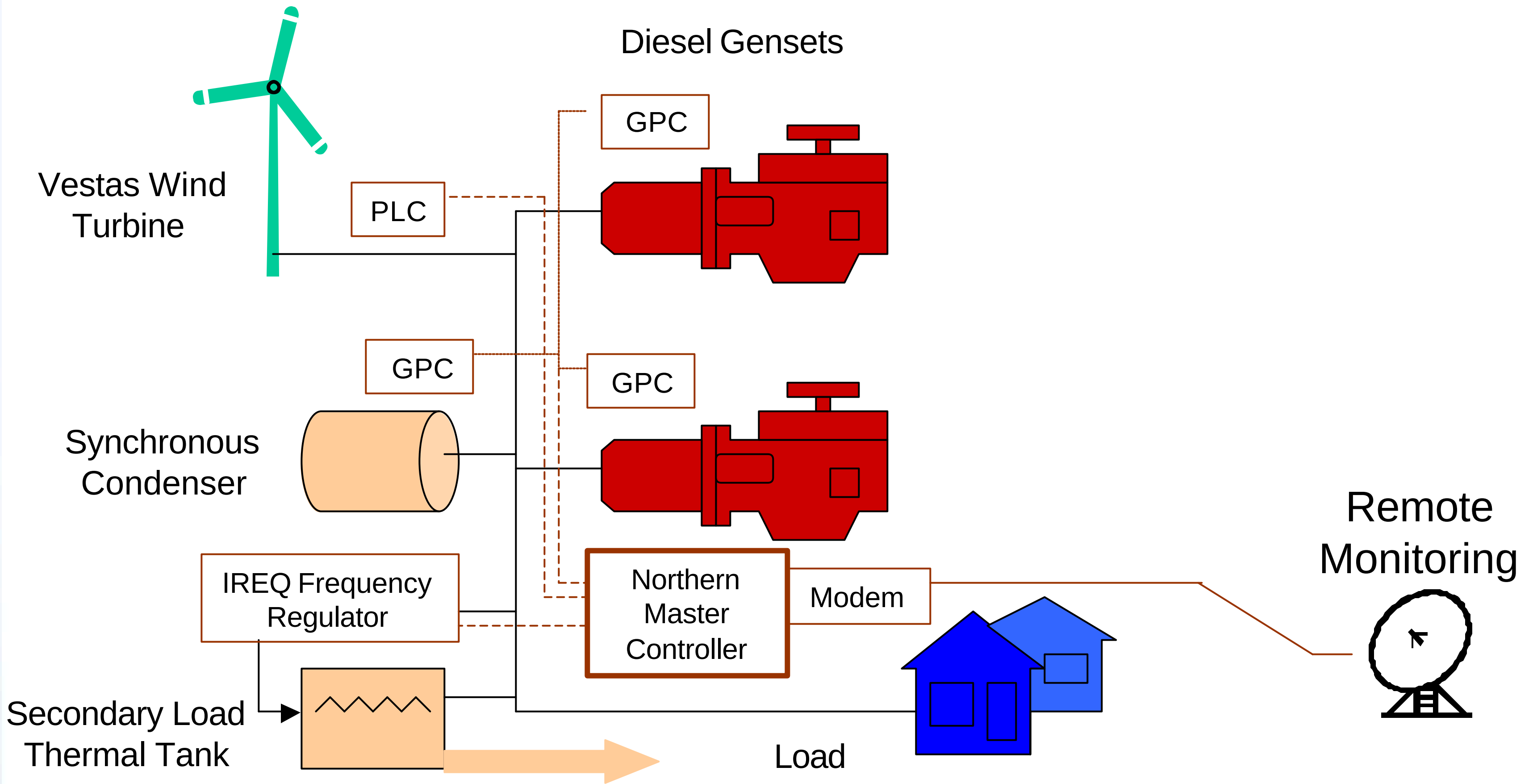


St. Paul Island

- Hybrid system with thermal storage

- World's first high penetration wind-diesel system
- District heating with co-generation
- Sophisticated controls
  - Maximize wind generation
  - Minimize fuel use, optimize efficiency
- Thermal storage
  - Multiple three-phase resistive heaters heats insulated water tank
- Remote monitoring & control

St. Paul Island conceptual design



St. Paul Island – seamless reliability

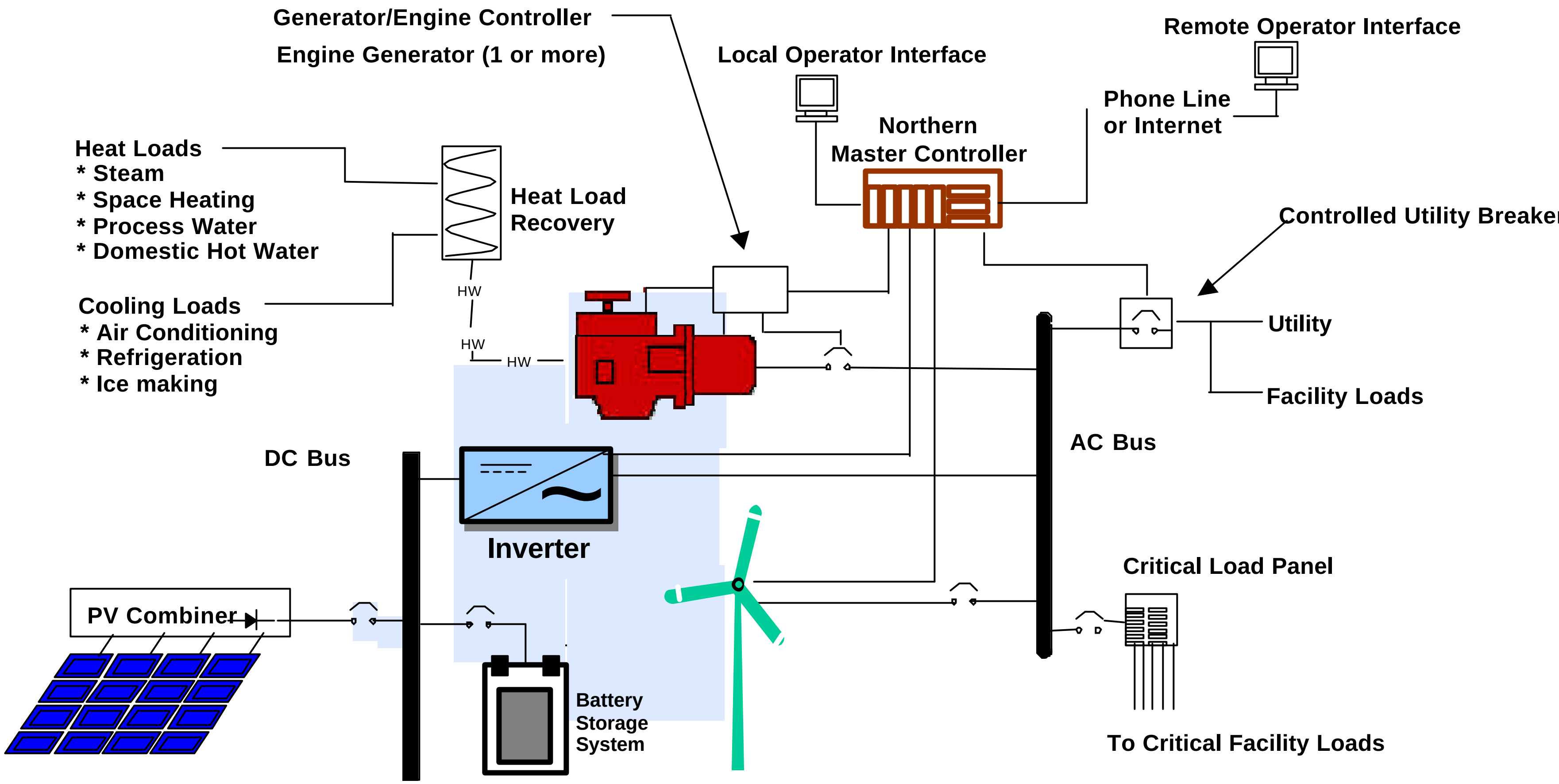
- Achieved target of >99.9% reliability
- Fuel savings electricity production: 3,346 gallons/yr
- Fuel savings heating : 8,940 gallons/yr
- 28% total fuel savings

- Optimization is a ongoing process!

Clean generation that matters

- Co-generation and PV

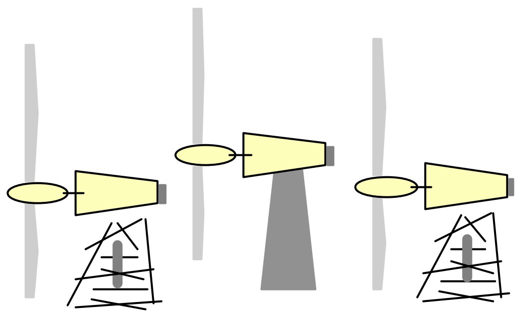
- Combining co-generation with PV gives lower payback, increased reliability, and <u>more power</u>

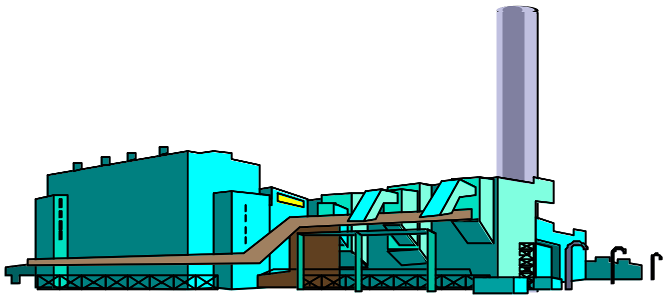


Isolated grid

- The advantage of fuel diversity with wind-diesel hybrids

Wind	**Diesel/Oil**
Low Operating Cost	High Operating Cost
High Capital Cost	Low Capital Cost
Non-Dispatchable	Dispatchable
No Fuel Supply/Cost Risk	Fuel Supply/Cost Risk
No Emissions	Emissions issue



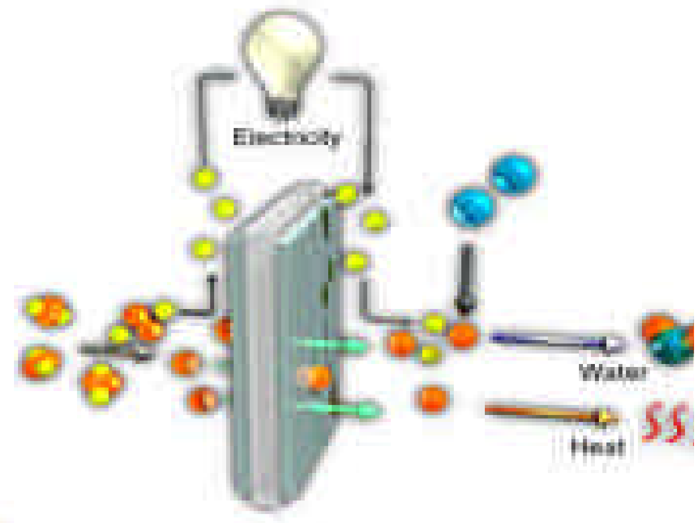


Triple-bottom-line hybrid architectures

	Co-generation and photovoltaics	Wind-diesel for isolated grids
Economic benefit	• 3 to 6 year payback on combined system	• Addition of wind increases reliability, hedges against fuel risk, and saves money
Environmental benefit	• PV clean • Co-generation 40% cleaner than average utility power	• Integration of renewables decreases overall emissions • Decreases risk of spills
Social benefit	• Realistic alterative to utility power	• Supports remote communities

The Future

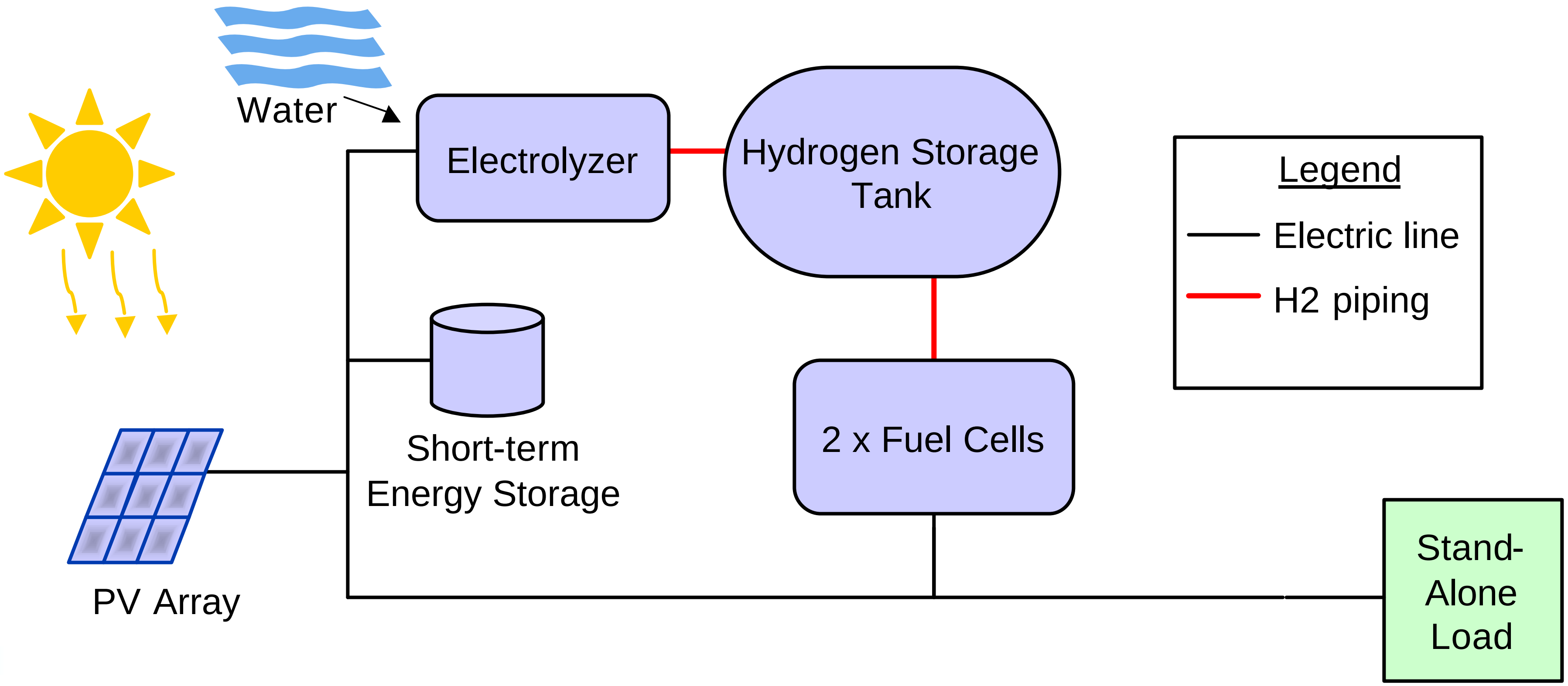
- Renewable Hydrogen Generation



- Key to a true hydrogen economy
- Unlimited, secure and domestic fuel supply
- Cleanest energy option
- Solution for intermittency of wind and solar
- Link between renewables and transportation

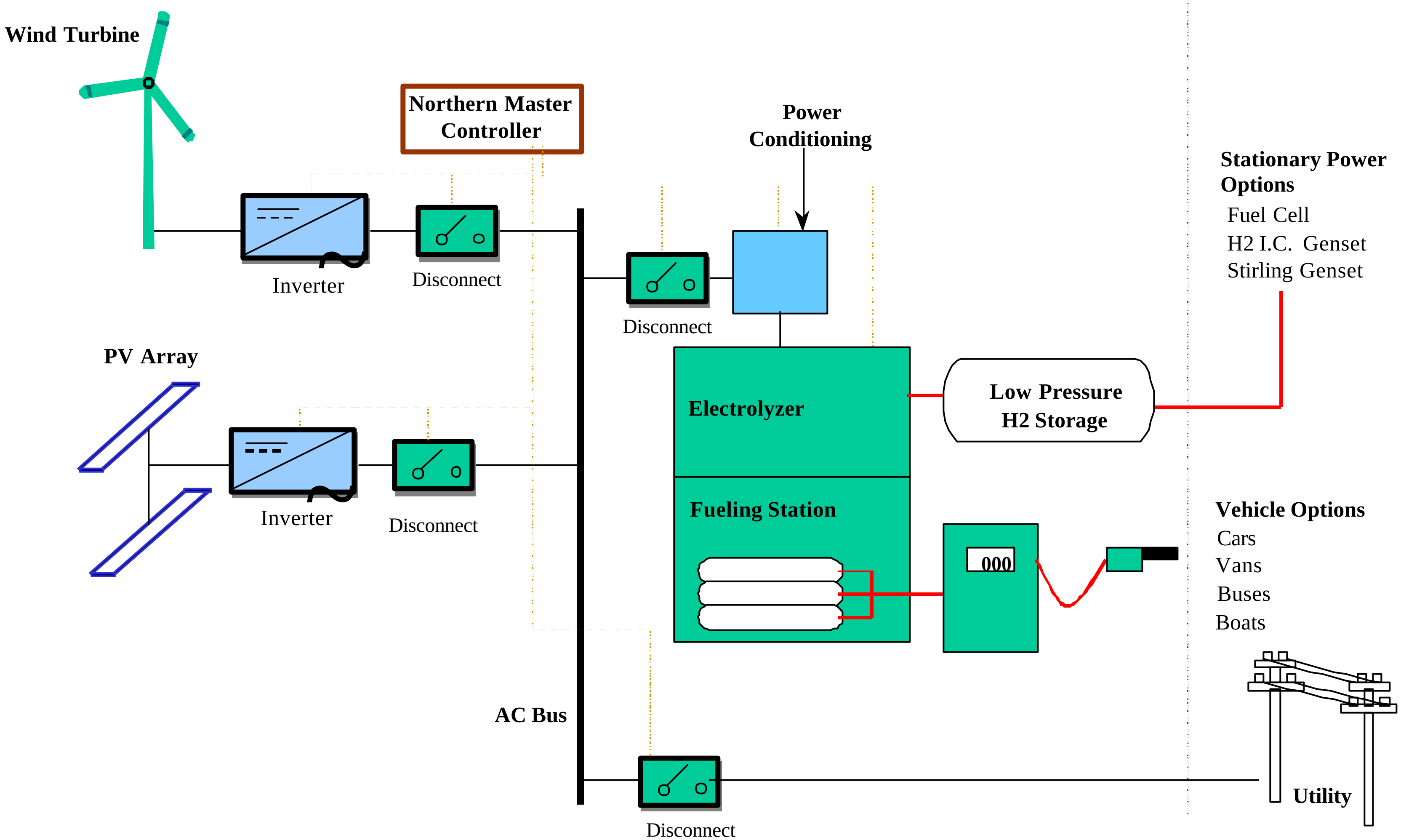
Project example

- Renewable Hydrogen Generation



Proof of concept demonstration project for 100% reliable power

Sample hydrogen hybrid architecture




I like renewables …
Somebody build a hybrid system!!!

MEETING THE PURE POWER DEMANDS OF THE NEW ENERGY MARKETPLACE

THANK YOU!

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